Real-Time Hydrographic and Meteorological Monitoring in Mobile Bay for Research and Education

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Abstract-The value of coastal observing systems is recognized by the U.S. Congress, the National Ocean Partnership Program, the Environmental Protection Agency, and the National Ocean and Atmospheric Administration. Recent reports by the Pew Oceans Commission and U.S. Commission on Ocean Policy have decried the lack of information from near coastal waters on which to base management decisions and recommended monitoring programs linked to strong research. Reasons for continuous, real-time observations of meteorological and hydrographic parameters include (1) continuous characterization of spatial and temporal patterns of change in water quality, (2) development of a permanent record of significant and human caused changes in environmental indicators over time and (3) support for research activities through the availability of consistent, scientifically valid data. An additional benefit of real-time observation is the potential for the public to track and learn about water quality conditions. Many coastal dwellers are uninformed about conditions in nearby estuaries because they do not have access to current information about parameters such as water temperature, salinity, dissolved oxygen levels and water level and they may fail to appreciate the complexity of interactions in estuarine ecosystems.

Dauphin Island Sea Lab and the Mobile Bay National Estuary Program have partnered with the University of South Alabama, local National Estuarine Research Reserves, the Alabama Department of Conservation State Land Division Coastal Program and the Alabama Lighthouse Association to provide real-time data on wind speed, wind direction, air temperature, barometric pressure, photosynthetically active radiation, precipitation, water temperature, dissolved oxygen, water height, and salinity at sites located throughout Mobile Bay. Up to the minute data are available in a user-friendly format at www.mymobilebay.com. Graphs of each parameter may be displayed and informative pop-up windows describe each parameter when selected by the viewer. Researchers may download the data in a spreadsheet format for further analysis.

INTRODUCTION

The value of coastal observing systems is recognized by the U.S. Congress, the National Ocean Partnership Program, the Environmental Protection Agency, and the National Ocean and Atmospheric Administration. Recent reports by the Pew Oceans Commission and U.S. Commission on Ocean Policy have decried the lack of information from near coastal waters on which to base management decisions and recommended monitoring programs linked to strong research. Reasons for continuous, real-time observation of meteorological and hydrographic parameters include (1) continuous characterization of spatial and temporal patterns of change in water quality, (2) development of a permanent record of significant and human caused changes in environmental indicators over time and (3) support for research activities through the availability of consistent, scientifically valid data [1]. An additional benefit of real-time observation is the potential for the public to track and learn about water quality conditions. Many coastal dwellers are uninformed about conditions in nearby estuaries because they do not have access to current information about parameters such as water temperature, salinity, dissolved oxygen levels and water level and they may fail to appreciate the complexity of interactions in estuarine ecosystems.

Most marine stations have a history of environmental monitoring. The venerable Marine Biological Laboratory at Woods Hole probably holds the U.S. record for the longest historic span of seawater temperatures, going back to the late 1800s [2]. Dauphin Island Sea Lab (DISL) began taking seawater temperatures and twice daily weather observations over 35 years ago. By no stretch of the imagination automated, these observations involved a staff member, or more often, a graduate student walking out on the pier, taking the water temperature with a bucket thermometer and calling in the results of the weather observations to the local National Weather Service Office. From these humble beginnings, the present automated system of real-time coastal environmental observations gradually evolved.

Automated data gathering in Mobile Bay began in 1974, with a partnership between NASA's Marshall Space Flight Center and DISL that resulted not only in automated data collection from anchored buoy systems for a short period of time [3] but also in the acquisition of weather observation equipment with recording capability [4]. Strip chart or punch tape recordings of wind speed and direction, barometric pressure, and precipitation formed the backbone of a Meteorological Observation Station located at the East end of Dauphin Island with the objectives of (1) documenting and characterizing the meteorological environment of coastal Alabama; (2) serving, on a cooperative basis, as a coastal meteorological and oceanographic substation for the National Weather Service; and (3) providing a public service to the residents and visitors of Dauphin Island by making observations available to the public [5].

After nearly 10 years of making manual observations and digitizing analog records, the station was more fully automated when low cost personal computers became readily available in the 1980s. Meteorological output from sensors was stored directly to magnetic media. Twice daily observations, which included oceanographic information, nevertheless continued to supplement the automated data recording until 1996.

At that time, DISL again began to experiment with collecting hydrographic data in real-time, along with the meteorological data. A variety of combinations of instrumentation and communication equipment were used with varying success until a standard configuration evolved which proved to be reliable. The DISL station was reconfigured in 2003 as a fully automated hydrographic and meteorological station with data available real-time via the web. An identical station was added at Meaher Park at the northern extreme of Mobile Bay later that same year. Finally, a similar station, with the added ability to profile vertically in the water column, was added in the middle of Mobile Bay in 2005 (Figure 1).

METADATA, DATA AND QUALITY ASSURANCE

Stations are located at Meaher Park (30° 40.028' N, 87° 56.188' W), Middle Bay Light (30° 26.2' N, 88° 00.7' W) and Dauphin Island Sea Lab (30° 15.075' N, 88° 04.670' W). Meteorological data are single observations taken at 1 minute intervals. Hydrographic data from optical sensors (dissolved oxygen, chlorophyll, and turbidity) are burst averages over 24 seconds at 2 hertz; the remaining hydrographic observations are burst averages over 4 seconds at 2 hertz. Parameters measured by the coastal observing system are listed in Table I. Salinity is derived from conductivity and expressed in Practical Salinity Units. Percent saturation of dissolved oxygen is derived from measured dissolved oxygen, temperature and salinity. The MBL station samples hydrographic parameters at different depths in the water column automatically every hour. At the top of the hour, the profiler moves the sonde to 3 meters below the surface where it takes its first measurement. After about two minutes, the time required to complete a measurement, the profiler moves the sonde up 0.5 meters and begins taking a second measurement. The sampling continues with a reading every 0.5 meters until the sonde reaches a depth of 0.5 meters where the final measurement is taken. After the final reading, the sonde descends to 2.5 meters where it waits for the next hour's profile. One profile requires approximately fifteen minutes to complete, two minutes for each of six measurements plus time for the winch to move the probe. Metadata are maintained in a format searchable by key word, geographic location or date at the National Coastal Data Development Center at

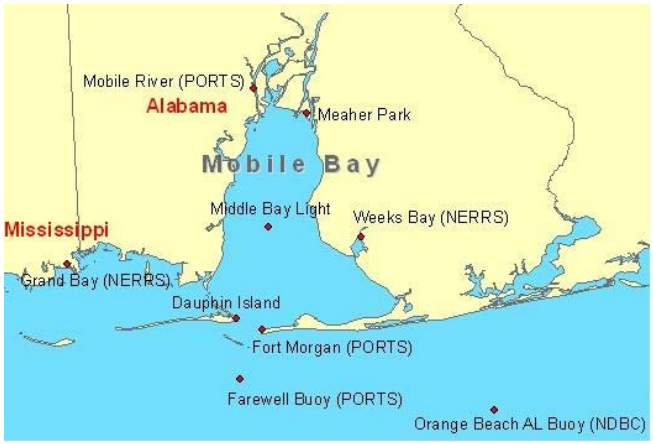

Figure 1. Location of real time stations in coastal Alabama.

http://portal.ncddc.noaa.gov/portal/jsp/search_options.jsp and may also be found at http://dim.disl.org/metadata_folder/3.htm.

Local data are continuously available at http://www.mymobilebay.com. Pages are updated every 20 minutes at DI and MP and every 30 minutes at MBL. Older data are available in graphic displays of 1, 5, 10 and 30 day duration. Researchers may also download data from the website in a spreadsheet format for further analysis.

Additional public access is accomplished by automatically routing selected data to the National Data Buoy Center for dissemination on their national website (http://www.ndbc.noaa.gov/maps/Alabama_inset.shtml), in both real-time and in archived form. Similarly, data are served to the Gulf of Mexico Coastal Ocean Observing System portal in near real-time to update their website (http://gcoos.rsmas.miami.edu). Beginning in 2008, data from Mobile Bay became available on an Integrated Ocean Observing System test bed for interoperability at http://www.openioos.org/real_time_data/gm_sos.html.

One of the biggest challenges of real-time data display is to insure that the data displayed are valid. Because of the high data volume (one record every minute for meteorological data, and one record every 30 minutes for hydrographic data), automatic range checking is the first line of defense against displaying spurious data. Outliers are written into the database and flagged as questionable but not displayed on the website. Incoming range-checked data, each with a unique timestamp and station code, are then subject to regular visual inspection for: (1) instrument or communication failure, (2) threshold checks and (3) rate of change checks and individual observations are flagged in the database by a technician as 'bad', 'questionable' or 'good'. All data downloads include quality control flags for each observation. Reference [6] gives a detailed review of the quality assurance sequence.

TABLE I

PARAMETERS MEASURED AT THE THREE DISL STATIONS; DAUPHIN ISLAND (DI), MIDDLE BAY LIGHT (MBL) AND MEAHER PARK (MP). (* not quality controlled or displayed real-time)

Meteorological Parameter taken every minute	**Units**	**Hydrographic Parameter taken every 30 minutes at DI & MP; every hour at MBL**	**Units**
precipitation	total in inches each 60 minutes	water temperature	degrees Celsius
air temperature	degrees Celsius, + 60 minute average	conductivity	millisiemens/centimeter
solar radiation	kilowatts/meter^{2}, + 60 minute average	dissolved oxygen	percent saturation and milligrams/liter
quantum radiation	microeinsteins/meter^{2}/second, + 60 minute average	depth	feet (DI=relative to mean lower low)
wind direction, 1 and 10 minute average	degrees from north	turbidity*	nephlometric turbidity units
wind speed, 1 and 10 minute average	knots	chlorophyll*	micrograms/liter
barometric pressure	inches of mercury, + 60 minute average		
relative humidity (MBL only)	percentage		

PARTNERSHIPS AND ENGAGING THE PUBLIC

Partnerships are crucial, not only for insuring continued support, but for disseminating the data and increasing its value. Automatic collection and distribution of meteorological data at DISL began with a partnership with both NASA and the National Weather Service to provide the necessary equipment [2]. The current generation of hydrographic and meteorological data collection and display began with a partnership with the Mobile Bay National Estuary Program to supply funding and program management. Several programs within the University of South Alabama and the Alabama Department of Conservation State Land Division Coastal Program supplied funding and equipment necessary to advance their research and management interests in Mobile Bay. The Alabama Lighthouse Association allowed installation of equipment on an historic structure. Louisiana Universities Marine Consortium provided information technology critical to developing our system so that information could be exchanged seamlessly [7]. The cooperation provided by these entities and others have sustained the monitoring program, enhanced sharing of data and contributed to a database of water quality conditions.

The National Data Buoy Center and the Gulf of Mexico Coastal Ocean Observing System were mentioned earlier as partners in disseminating data. Likewise, data collection in Mobile Bay by federal agencies may be accessed through our webpage. To consolidate information sources in the region, data from the two National Estuarine Research Reserves (NERRS), three Physical Oceanographic Real-Time System (PORTS) stations and a National Data Buoy Center (NDBC) offshore platform are linked to the homepage (Figure 1).

In addition to the webpage, real-time observations are part of an interpretive display at DISL's public aquarium. Meteorological and hydrographic data displayed real-time to the public are intended to educate visitors to both the aquarium and the website about the background variability in water quality measurements and to demonstrate interactions between them in estuarine environments. Understanding is facilitated by informative pop-ups describing each parameter when that parameter is clicked on the webpage. Visitors to the website frequently use the weather station data as a source of information on local coastal conditions to aid in decision making relative to their activities. Non-DISL, unique visitors to the website averaged over 2100 visits/month over the past year and many of these visitors return time after time for additional information.

All data are archived as part of a long-term program monitoring coastal weather conditions and baseline hydrographic conditions. Researchers at both DISL and other institutions use the data to correlate climate and hydrography with their study variables. Results of this monitoring program have economic and environmental impacts on the local community and resource managers. Information from the stations assist policy makers and resource managers on issues as diverse as reservoir and dam operation, hydroelectric generation, shrimp and oyster productivity, regional water compacts, and other water quality questions. In general, people will not support what they do not understand. Real-

time displays and easily accessible archived data give the local community the ability to evaluate resource needs and contribute to policy decisions made by resource managers. The interaction helps educate the public on the complexity of the Mobile Bay and Mobile-Tensaw Delta ecosystems and the myriad impacts of hydrologic alterations.

SUMMARY

Dauphin Island Sea Lab and the Mobile Bay National Estuary Program have partnered with the University of South Alabama, local National Estuarine Research Reserves, the Alabama Department of Conservation State Land Division Coastal Program and the Alabama Lighthouse Association to provide real-time data on wind speed, wind direction, air temperature, barometric pressure, photosynthetically active radiation, precipitation, water temperature, dissolved oxygen, water height, and salinity at sites located throughout Mobile Bay. These up to the minute data are available in a user-friendly format at http://www.mymobilebay.com. Informative pop-ups describe each parameter and graphs of each may be displayed by the visitor to the website. Researchers may download the data in a spreadsheet format for further analysis.

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